Final Project Report
Detailed Form

I. Title of Proposed Project:

IoT System for Public Health and Safety Monitoring with Ubiquitous Location Tracking

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IV. Project Report

i) Introduction

In today's highly digitized society, ICT technologies play a critical role in preserving health and safety of vulnerable citizen especially women, children and the elderly. In recent years, there is a growing need for monitoring citizen's lifestyle including their health status. Besides health, continuous awareness of their current location is also becoming more critical.

The main objective of this project is to design and develop a collaborative framework which facilitates real-time tracking of a target person even when GPS signal is not available, while collecting motion data to infer his or her lifestyle and health status. The framework orchestrates a wide range of technologies such as localization technologies, machine learning and AI, sensor data analytics and cloud computing. The overall framework design also takes into consideration the culture, lifestyles, behaviours and infrastructures of ASEAN countries.

On location tracking, a mobile and cloud-based Indoor Location Platform (ILP) which incorporates multimodal localization means and assisted by other sensor fusion techniques is developed. In this platform, GPS and non-GPS positioning systems such as Wi-Fi/BLE fingerprinting, IR-UWB positioning, sensor-based and a hybrid of these localization techniques are adopted to provide continuous tracking of the subject of interest in both indoor and outdoor environments. Extensive trials have been carried out in not only laboratory testbeds, but also in factories and other commercial premises.

On health or lifestyle monitoring, harvesting of motion data and context reasoning, using the IntelliHealth Solutions were carried out to assess, monitor and to provide feedback on a person's lifestyle. An intelligent knowledge base is formed and this enables the development of various transient wearable health OS solutions. In this project, wearable motion interfacing and reasoning devices for general public are developed to support trials and data collections involving people from public.

ii) Project Activities

(1) Development and Implement

Figure 1 depicts the overall system architecture developed in this project. This architecture serves as a reference architecture for various modules or submodules developed by various partners and how they interact with each other. As shown there are general two main components: 1) Smartphone/Embedded device and 2) Server/Cloud.

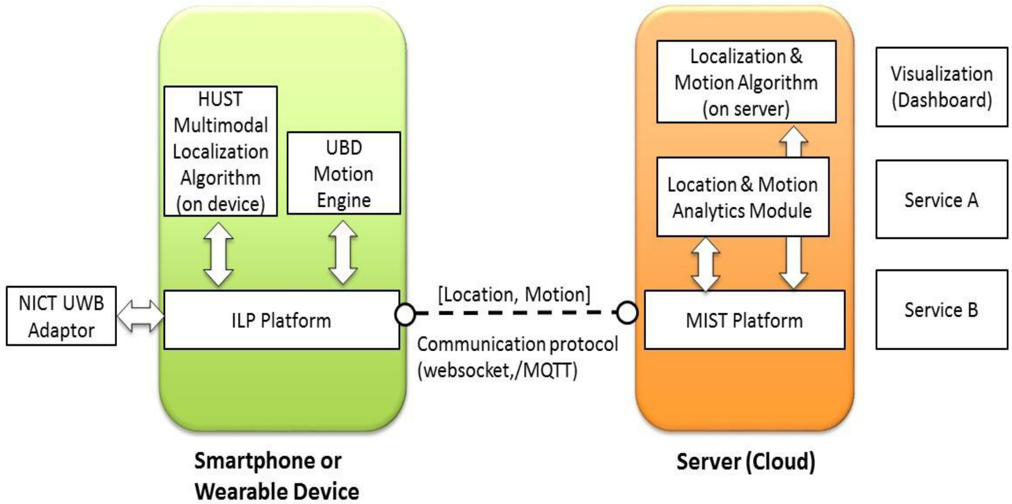


Figure 1: Overall System Architecture

1) Mobile-Cloud Indoor Location Platform (ILP) supporting Wi-Fi and BLE positioning:

In this project MIMOS develops a collaborative Mobile-Cloud Indoor Positioning platform (Mi-ILP). This platform offers both mobile-end and server-end position computation depending on the usage scenario. Various commercial grade features such as flexible SDK and user-friendly site survey tool have also been provided. In addition, backend data analytic and visualization platform (Mi-MIST) has also been made available to partners to perform various customized analysis.

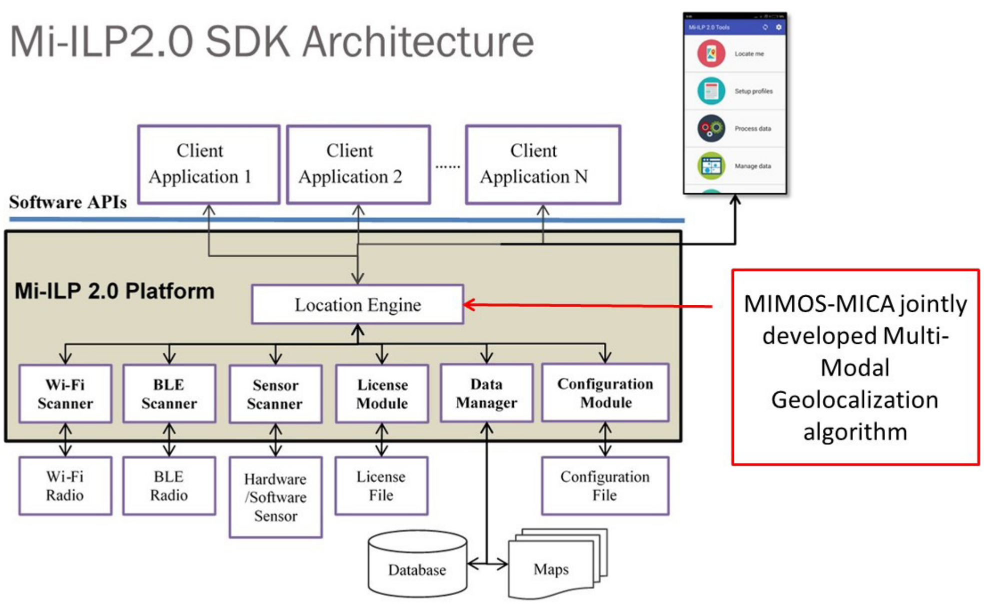


Figure 2: Mobile-Cloud Indoor Location Platform (ILP)

Within the ILP platform, the research activity is mainly focused on multimodal algorithm design and development. An extensive simulation work has been carried out in order to decide on the best algorithms to be applied on different use case scenarios and environments. In this project, different machine learning, statistical and hybrid algorithms have been developed and implemented in the platform.

2) ILP with UWB Positioning Adaptor

In order to achieve an enhanced submeter accuracy, an Impulse Radio Ultra-Wide Band (IR-UWB) positioning system developed by NICT based on two-way ranging (TWR) algorithm is integrated into the framework system. A testbed was setup in MIMOS BITX Laboratory with an area size of approximately 2000 square feet. Figure 3 illustrates the testbed architecture design. As shown, the UWB adaptor is integrated with MIMOS ILP platform over Ethernet via NICT-MIMOS proprietary protocols.

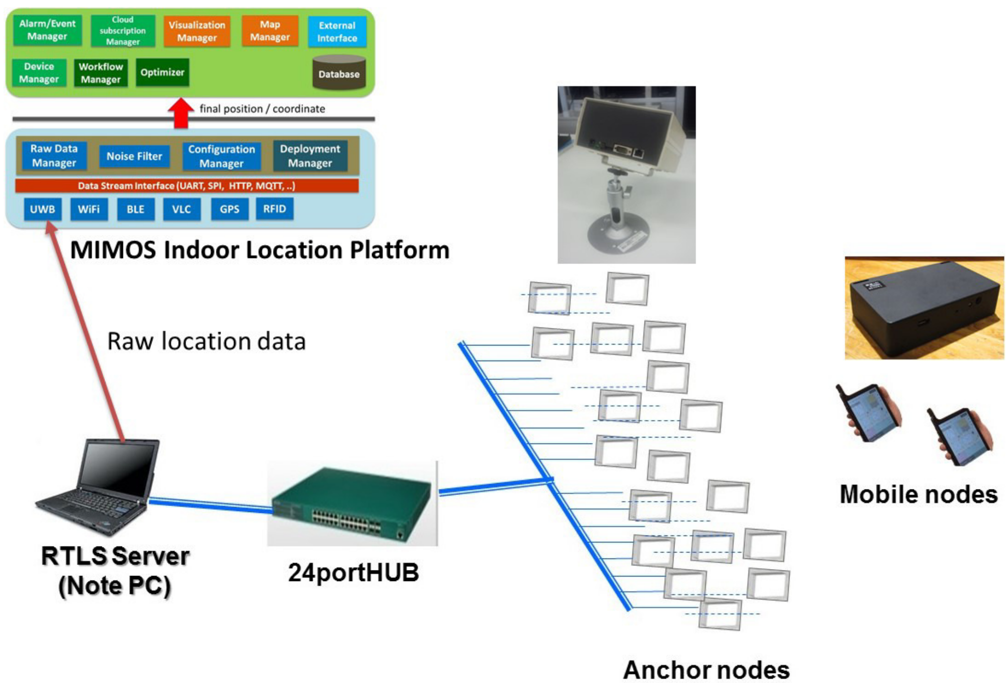
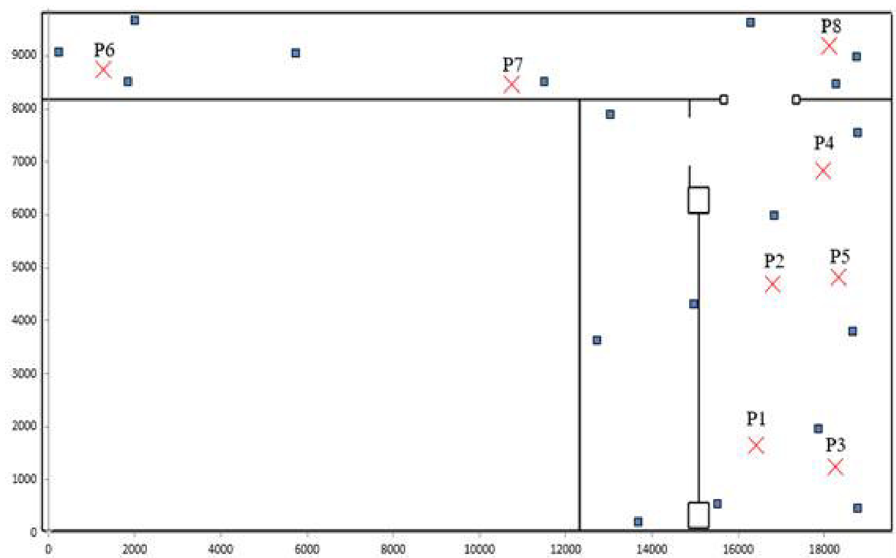


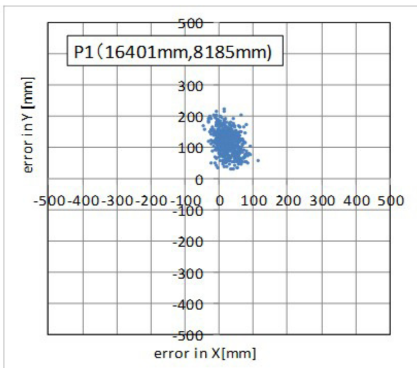
Figure 3: ILP-UWB Adaptor Integrated Testbed

The following pictures depict the setup and testing activities. Through the mobile nodes, IR-UWB network provides the required sub meter positioning accuracy. An extensive ranging and positioning accuracy testing activities were carried out before this system was handed over to MIMOS for further development.

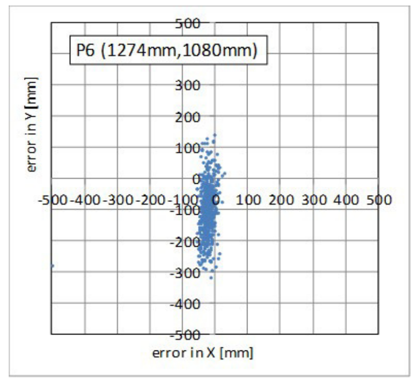


Floorplan

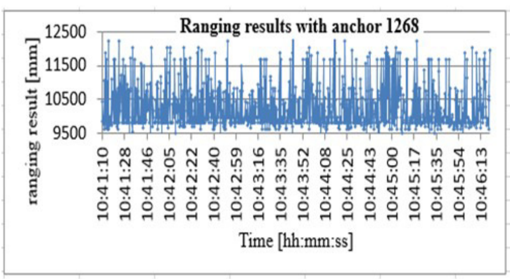
Figure 4: Installation and Setup

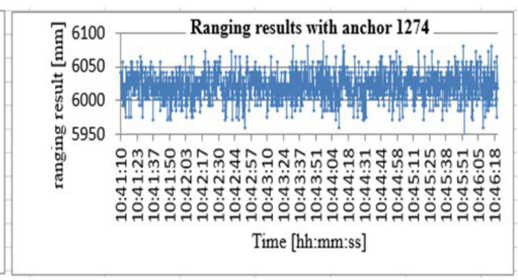


Position 1: within 20cm



Position 2: within 40cm





Position 1: Ranging Result with different anchors

Figure 5: Accuracy and Ranging Tests

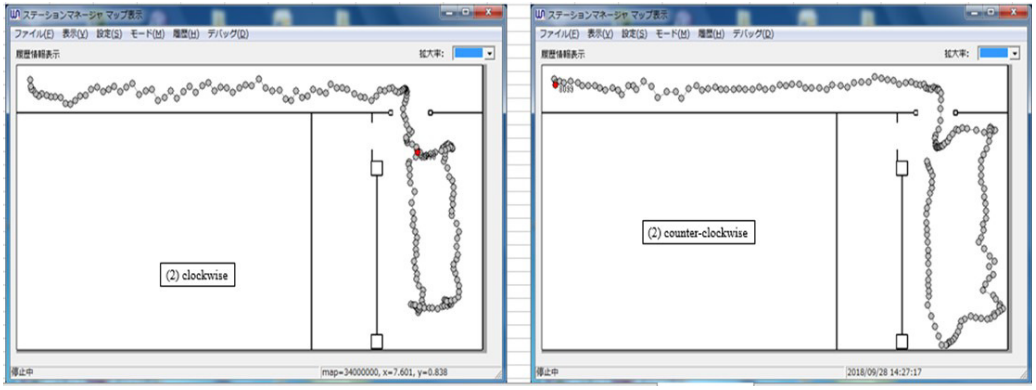


Figure 6: Walking Test

The overall test results show that the positioning accuracy falls within 20cm if there is no reflection. Certain areas experienced high reflection due to the existence of TV screens. The results also show that body effect has a significant effect on the accuracy. Further filtering at the upper layer is expected to filter out odd data caused by reflection.

3) Multimodal Localization Module

It is known that there is no single technology which can localize a user in a large space including buildings: GPS technology is suitable only for outdoor areas; RFID tags are mainly used for close localization of objects; smartphone cells are too often imprecise for real applications, etc. One possibility consists of combining multiple technologies to increase the overall coverage and accuracy of the geo-location service. For example, it is possible thus to estimate the position of a user in relation to the smartphone cells, triangulating their position in wireless networks (Wi-Fi, Bluetooth, ZigBee, etc.) and add position information coming from GPS positioning, RFID tags or cameras. This approach makes use of heterogeneous data, which implies that the environment where the user evolves is equipped with different sensors and devices like cameras, RFID readers and wireless antennas. The R&D work consists of achieving a geo-location platform working in real time for a perceptual and reactive environment at the scale of a campus. The major constraint is to achieve an evolutionary platform allowing adding new elements as new classes of sensor, new algorithm of data fusion and localization or new user services.

In this module a model-based approach, with the help of the map information is adopted. To determine the user location, space is divided into grid points. At each point, the user appearance probability and precision are calculated with information provided from all available localization technologies. Since each localization technology provides results at different moments, the time passed since the last result received from a technology to the current system time can affect the final result. Besides, each application may require a different acceptable precision, so on the basis of the given precision from each application, the location with highest probability is chosen as user localization result. If the environment is large where the number of points is big, it is possible to reduce the searching time by first gridifying the space with fewer points to find a rough position, then repeating the same process once or twice with the subspace around this rough position for fine tuning.

The system makes use of the results from multiple technologies as inputs and gives out user location to applications as output. Event-driving approach is used, i.e., each input will provide new localization results to ensure real-time availability. API module contributes as an open platform to extract useful information from inputs and store in the database. Information extraction module extracts necessary information from database as well as receives the precision limitation from applications then provides them to next module. Calculating module does the main processing function and produces user localization result. Depending on applications and their required precisions, results would be different. Subsequently, the outputs including user location, precision and probability are sent to applications and fed back to be stored in database for next calculation tasks. Figure 7 as follows illustrates the internal architecture of the Multimodal Localization Module.

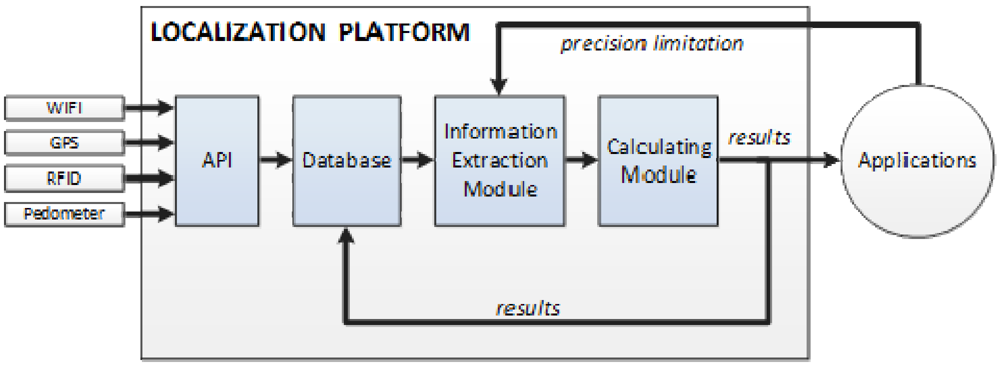


Figure 7: Multimodal Localization Module Architecture

4) Motion Reasoning Module:

This module contains custom-built multisensory wearable suit with cloud connectivity interfaced Artificial Intelligent techniques and Deep Reinforcement Learning algorithms in order to detect, to monitor and to analyze biofeedback control and visualization during human daily activities. The implementation uses smart shoes which consist of wearable wireless multi-sensor insole. The sensors acquire foot biomechanics parameters from the toe, left ball right ball and heel during human gait activities and store and update the data in the Amazon Web Services (AWS) cloud. Deep Neural Networks (DNN) is employed to establish reference features; cadence and gait abnormality and normality as a function of the left and right support of foot which is considered as transient health status. A Case-based reasoning approach is adopted to personalize the normative data of human walk which allows classifying the gait using left support and right support based on the cadence in real time. Cloud computing is performed in order to detect the gait abnormality of left support and right support which are visualized as actual health status on Samsung Gear S3. Figure 8 as follows depicts the overall Motion Reasoning system architecture which consists of Master-IoT, Slave-IoT and Knowledge Base in Cloud.

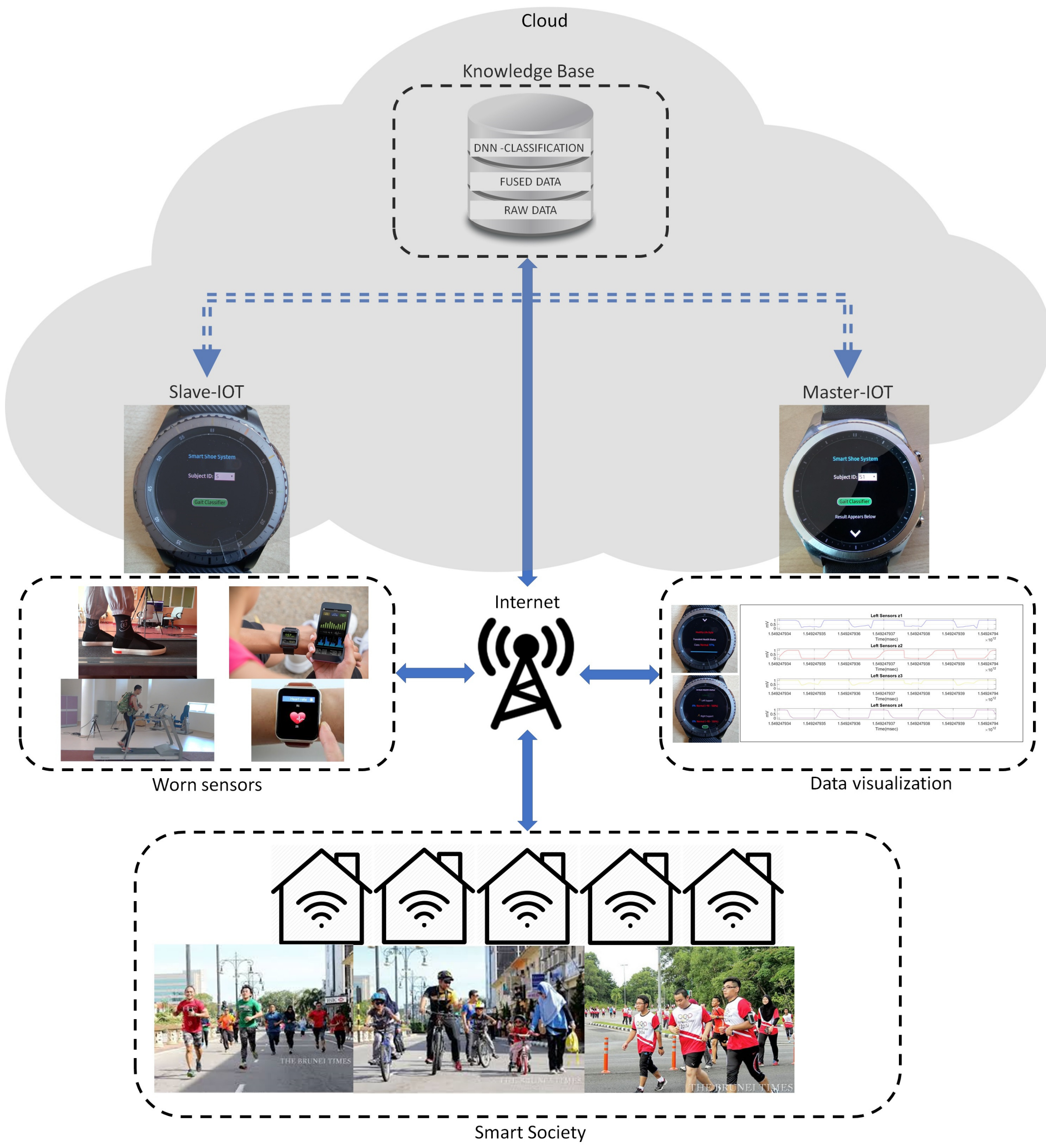


Figure 8: Motion Reasoning System Architecture

On Motion(Health)-Location data binding, two approaches as shown in Figure 9 as follows are explored.

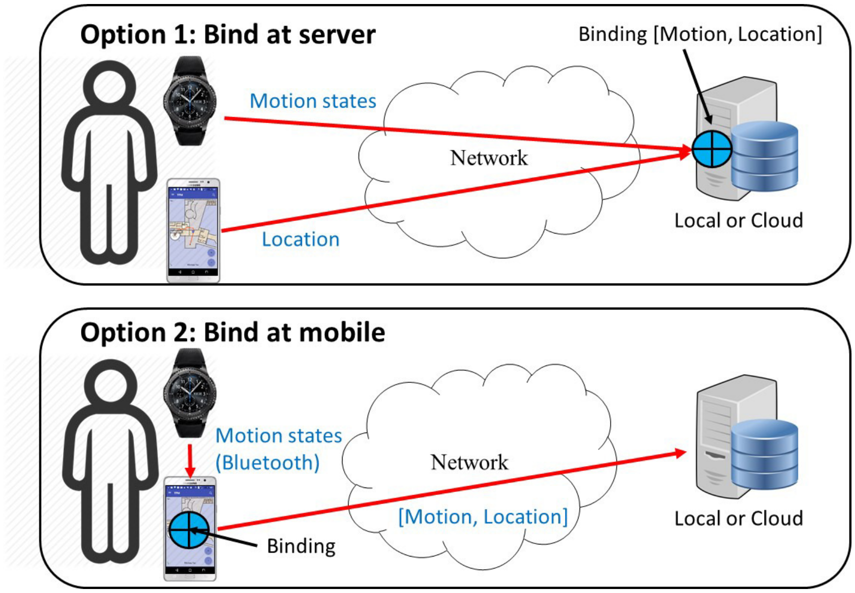


Figure 9: Binding of Motion (Health) and Location Data on Cloud

Each option has its own advantages and disadvantages. Overall, the option 1 is easier to implement as it avoids the effort to integrate different types and models of devices with the mobile app. Moreover, most commercial wearable devices come with built-in capability that enable it to connect to the cloud directly. When both health and location data are available at the cloud, the binding work will be straightforward provided the timestamp is correctly labelled at the receiver end.

(2) Leveraged Resources and Participants

Table 1 describes how various project members have contributed to the project.

Table 1: Work packages and actual deliverables

Work packages	**Actual Deliverables**
1. Mobile/Embedded Platform (Lead: MIMOS/NICT) Design and implementation of embedded platform that supports continuous location tracking and motion reasoning on commercially available smartphones or specially designed, low-cost and energy-efficient wearable devices	• Mobile/Cloud ILP platform (Android/iOS/Cloud) from MIMOS • Wi-Fi based tags/wearables from MIMOS • IR-UWB note PC, anchors, tags and POE switch from NICT • Master-Slave IoT Smart shoes for Gait Analysis from UBD
2. Multimodal Geospatial Localization Module (Lead: MICA) Development and integration new multimodal geospatial localization technologies which opportunistically harvest heterogeneous signals available for localization such as GPS, GSM, Wi-Fi, Bluetooth, UWB, sensors in order	• Multimodal Localization Module and Collaborative Tracking Framework from MICA

to realize ubiquitous location tracking anytime anywhere	
3. Motion Reasoning Module (Lead: UBD) Development and integration of Motion Reasoning module based on UBD's hybrid OS architecture	• Hybrid OS Master-Slave IoT Motion Reasoning Module by UBD
4. Server Monitor and Analytics (Lead: MIMOS) Development of server-end modules to monitor and analyze citizen's lifestyle, health and location. Using Mi-MIST platform to host data and analytic modules	• Mi-MIST monitoring/analytic module from MIMOS
5. Pilot Trials (Lead: Depending on location) Pilot trials in selected ASEAN cities such as Hanoi, Kuala Lumpur and Bandar Sri Begawan. Ideally such trials are to be performed with local mobile operators or commercial partners	Live trials and experiments • Public trial of Master-Slave IoT System using Smart Shoe, Brunei (partner with the Ministry of Defense, Ministry of Culture, Youth and Sports and Gifu University) • Private trial of Mobile ILP in VINCOM MEGA MALL TIMES CITY, Hanoi. • Private trial of Mobile ILP in IOI City Mall and Empire Subang Gallery Mall, Kuala Lumpur (partner with MySon) • Commercial trial of Mobile ILP in Chatuchak Market, Bangkok (partner with Tractive) • Commercial trial of Cloud ILP with IR-UWB in a food production factory, Kuala Lumpur (partner with Teksoft) • Commercial trial of Cloud ILP with IR-UWB in a Custom steel work factory, Penang (parner with CGS).

(3) Findings and Outcomes

In this project, extensive experiments and trials were carried out. In this section, only some selected results are highlighted.

i) Localization Experiments

Large Scale Commercial

For indoor positioning system, large scale commercial deployments remain elusive due to various factors such as high deployment cost and/or lack of market drivers. Although the wireless fingerprinting approach is relatively low cost and fast to deploy, the accuracy of the system tends to deteriorate over time due to Wi-Fi access points (APs) being removed and shifted. Using Mobile-ILP platform with multimodal algorithms, we carried out a study on such deterioration, which we refer to as fingerprint health analysis on a 2 million square feet shopping mall in South of Kuala Lumpur, Malaysia. We focus our study on APs removal using the actual data collected from the premise. The study reveals the following findings: 1) Based on per location pin analysis, ~50% of APs belong to the mall operator which is a preferred group of APs for fingerprinting. For some location however, the number of operator-managed APs are too few for fingerprinting positioning approach. 2) To maintain mean error distance of ~5 meter, up to 80% of the APs can be removed using the selected positioning algorithms at some locations. At some other locations however, the accuracy will exceed 5m upon >20% of APs being removed. 3) On average, around 40% - 60% of the APs can be removed in random manner in order to maintain the accuracy of ~5m. Figure 11 shows the error distance performance of three selected machine learning and statistical algorithms.

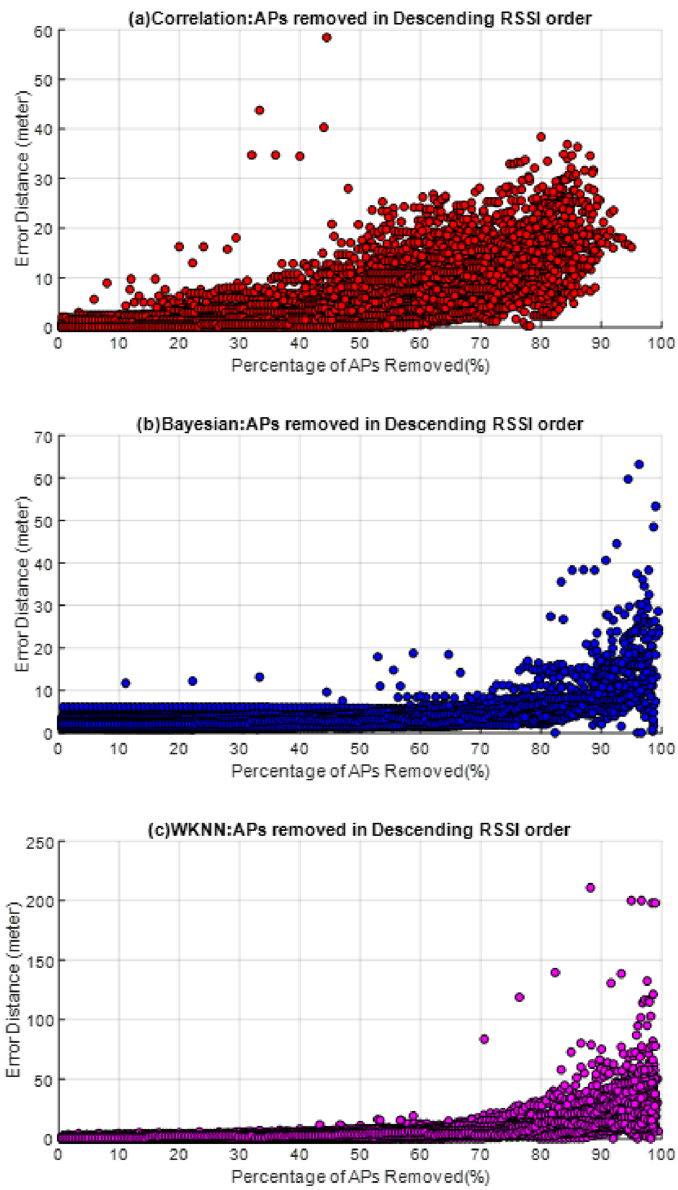


Figure 11: Error Distance Performance of Mobile-ILP [IJASEIT'2018]

Multi-User Collaborative Approach

For localization of multiple users, Bluetooth data from the smartphone is able to complement Wi-Fi based methods with additional information, by providing an approximation of the relative distances between users. In practice, both positions provided by Wi-Fi data and relative distance provided by Bluetooth data are subject to a certain degree of noise due to the uncertainty of radio propagation in complex indoor environments. In this study, two approaches, namely Non-temporal and Temporal ones, of collaborative positioning to combine these two cohabiting technologies are evaluated. In the Non-temporal approach, the model establishes an error observation function in a specific interval of the Bluetooth and Wi-Fi output. It is then able to reduce the positioning error by looking for ways to minimize the error function. The Temporal approach employs an extended error model that takes into account the time component between users' movements. For performance evaluation, several multi-user scenarios in an indoor environment are set up. Results show that for certain scenarios, the proposed approaches attain over 40% of improvement in terms of average accuracy.

Figure 12 shows the Distance Error (meter) performance of different approaches. As observed, the Temporal approach offers a significant improvement over non temporal and Wi-Fi only approaches.

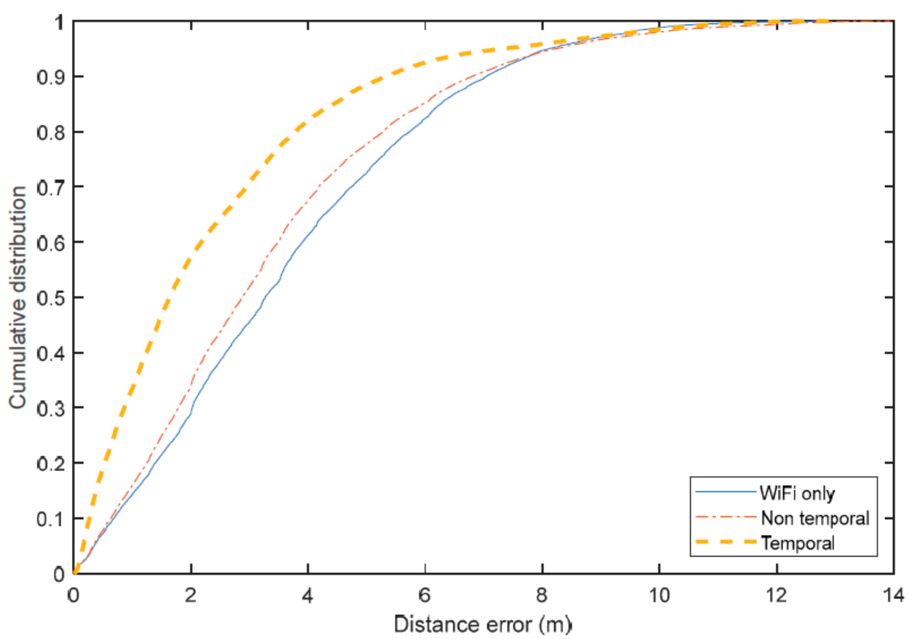


Figure 12: Distance Error (meter) Performance of Different Approaches [Sensor 2020]

Fusion with IMU and LiDAR

In this experiment, an autonomous navigation solution to localize Intelligent Vehicles in indoor environment is investigated. Here, a wireless sensor network-based approach replaced the GPS (Global Positioning System). A fusion framework for multiple sensors such as Wi-Fi access points, Inertial Measurement Unit (IMU) or LiDAR was carried out. The experiments took almost one-year duration in order to yield a stable result of mean global localization error at 0.5m as shown in figure 13.

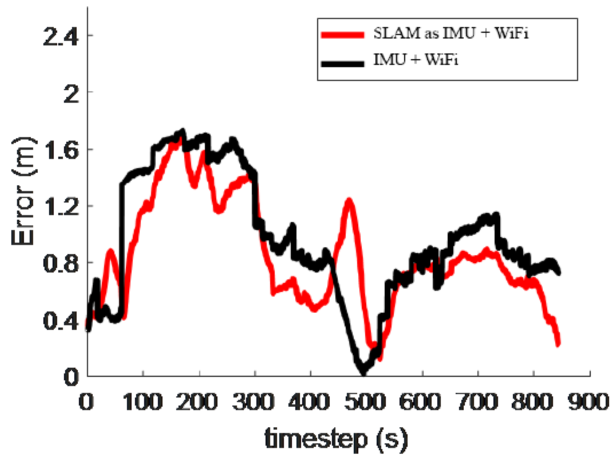
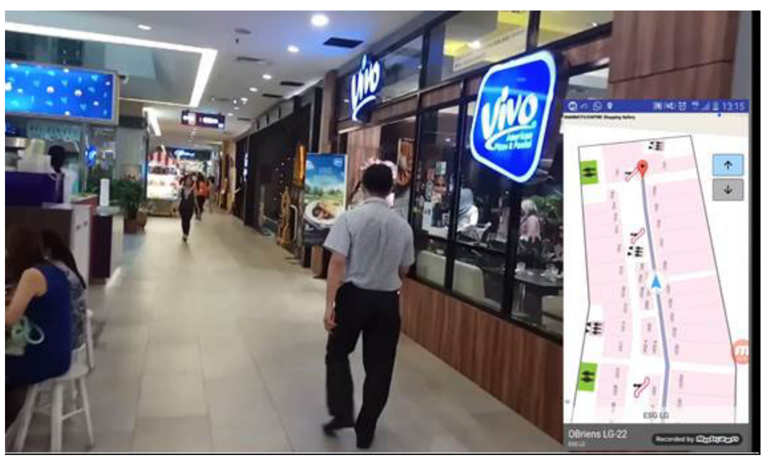


Figure 13: Localization error with laser-SLAM, IMU and Wi-Fi fusion [IEEE Access 2020]

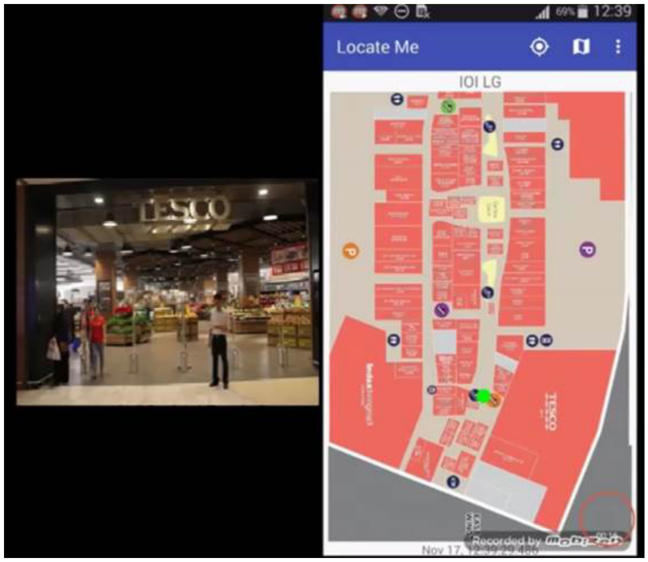
ii) Localization Live Trials

This section reports some of the selected live trials that took place in some shopping malls in Klang Valley (Greater KL), Hanoi and Bangkok. Selected use cases in some factories are also reported.

(a) Empire Subang Gallery, Subang Jaya, Malaysia.
(https://www.youtube.com/watch?v=zPCZEYe9Ri8)

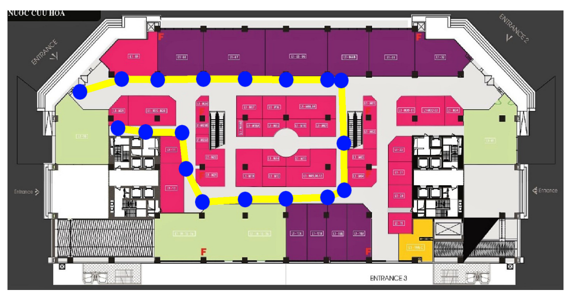


(b) IOI City Mall, Putrajaya, Malaysia.
(https://www.youtube.com/watch?v=6Uwyv9Vf2g8&t=48s)

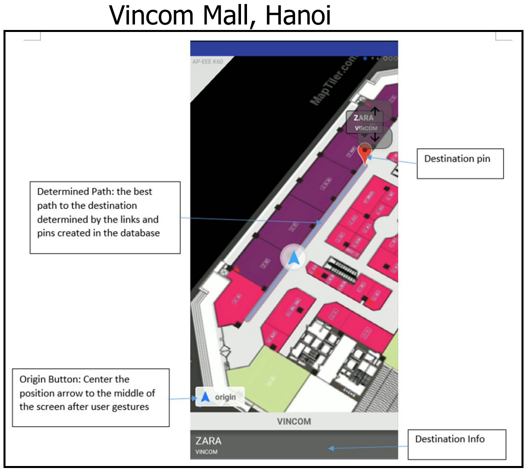


(c) VINCOM MEGA MALL TIMES CITY, Hanoi, Vietnam.

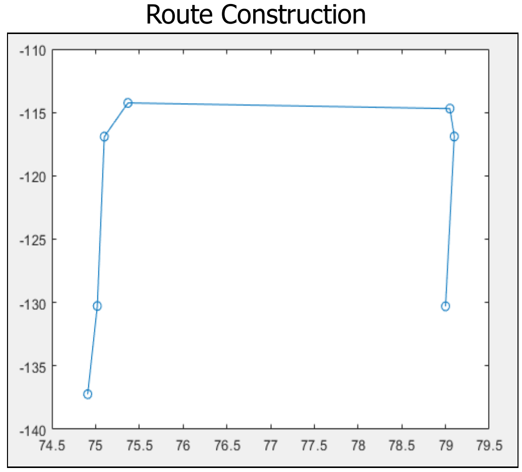
Vincom Mall, Hanoi



Route Construction



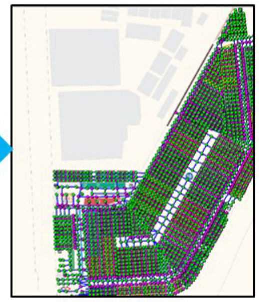
Mobile Snapshot



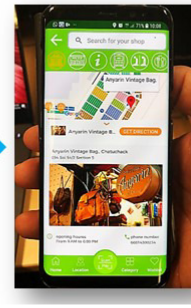
Positioning and Accuracy Tests

(d) Chatuchak Market, Bangkok, Thailand

Bird Eye View of Chatuchak

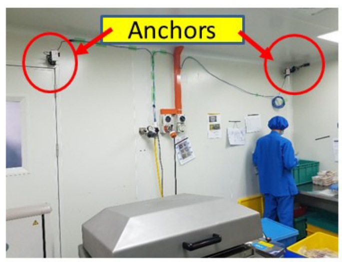


Navigation Layer Construction

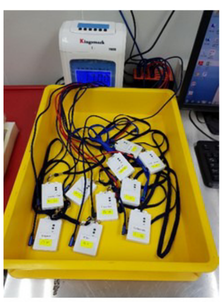


Mobile App

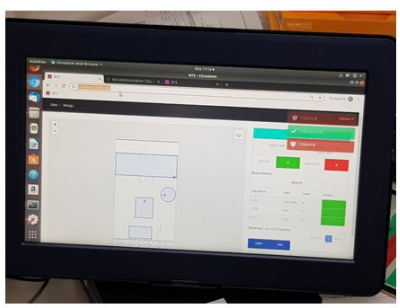
e) Food production Factory, Kuala Lumpur, Malaysia



Production Floor



IR-UWB Tags



Dashboard

Job Entry Terminal

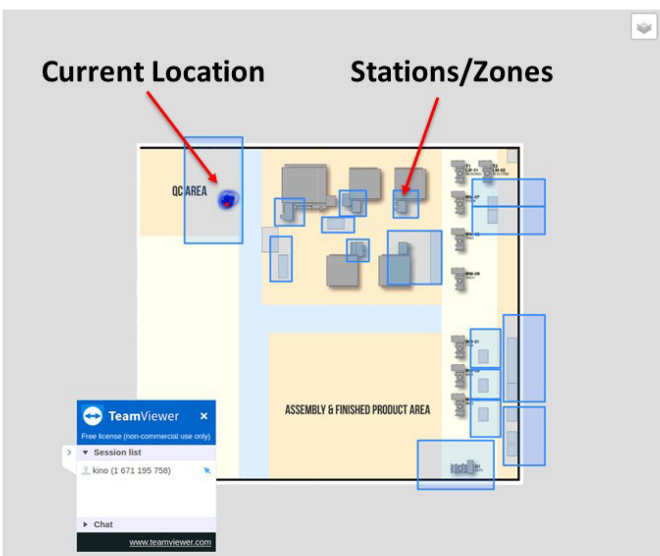
e) Custom Steel Work Factory, Penang, Malaysia

Production Floor

Production Floor

Tag Charging & Assignment Station

Trial Run



Tag zone, status

Monitoring Dashboard

Generally for shopping malls, accuracy of around 5m is achievable via Wi-Fi and around 3m can be achieved via BLE. Wi-Fi fingerprinting is fast to deploy due to widespread availability of Wi-Fi APs but maintaining the fingerprint database can be a huge challenge. For Android-based mobile based localization, the location update rate is slow (~3 to 5 seconds) due to long Wi-Fi scanning cycle. This may degrade the user experience of a fast moving person. For BLE, an update rate of around 1s can be achieved. For iOS-based system, Wi-Fi based location cannot be implemented due to its OS restriction. For BLE, iOS-based location achieves similar performance as Android. The deployment of BLE-based localization system however faces an uphill challenge due to high infrastructure cost faced.

For the manufacturing industry, use cases generally involve tracking of staff, asset and work in progress (WIP). The objectives are mainly for

- Improving productivity by reducing manual tasks such as record job and time
- Reducing time wasted on locating asset or WIP
- Improving work efficiency by studying the staff movement and activity over time in order to improve production line design
- Monitoring worker's health and safety.

To support these use cases, the cloud-based ILP system with device or tag-based tracking with location data processed and computed at the server end is developed.

i) Motion Reasoning Module

In this module, a biofeedback visualization of natural daily human activities for fitness development and performance enhancement using Master-Slave IoT devices is developed. Human test subjects with average age ± 38.6 were used to obtain the cadence of human walking in order to determine their Actual Health Status (AHS) and Transient Health Status (THS). Primary parameters experimented were Single Left Support (SLS) and Single Right Support (SRS) due to double support in the cadence to be vanished during brisk walking and running. This study uses ZeBlok smart shoes equipped with4 inertia measurement units (IMUs) on the toe, left ball, right ball and heel and the linear accelerometer inside the insole interfaced to the Bio-Informatics Cloud, deep neural network (DNN) tools and Samsung smart watches as IoT devices for biofeedback visualization in near real time. Master-Slave IoT hardware and software integration using cloud computing is built in order to establish knowledge base on Master-IoT device which provides THS of cadence monitored by health professionals (physiotherapist, doctors, trainers, athletes and soldiers). Slave-IoT is built for AHS during natural walking in order to produce biofeedback visualization report for health professionals and test subject under consideration as personalized healthcare solution. Thus, data availability and data redundancy provided using Master-Slave IoT devices facilitate the process of obtaining optimal solutions during biofeedback visualization.

The outcome has demonstrated the pattern set classification of SLS and SRS based on the cadence through the integration of neural networks and cloud computing. Master-Slave IoT devices are proven as an assistive personalized healthcare tool and as well as knowledge base created for health professionals. Hence, health professional is able to monitor and to improve the cadence of individuals and at the same time to enrich the knowledge base using novel patterns observed during daily active healthy life style. Master-IoT and Slave-IoT devices will immensely help in providing a better healthcare within the Brunei community and beyond within ASEAN, in particular athletes, soldiers and patients with gait abnormality.

(4) Broader Impact

The impacts of this project are discussed across the following verticals:

1. **Shopping malls**

   Shopping malls have always been a significant part of ASEAN citizen especially those in the large cities. With ever growing mall sizes and density, the need for navigation and tracking services increase accordingly. Positive feedbacks were received from technology partner during the trials. As the technology matures and cost becomes lower, it is foreseen that such services will be more widespread in the years to come.

2. Manufacturing

Real-time tracking of staff, asset and workflow are not commonly practiced in the ASEAN manufacturing industry at present. There is still a high dependency on manual, labour-intensive tasks. As the world is embracing Industry 4.0 transformation, there is an increasing interest for real-time tracking services including health and safety monitoring amongst the ASEAN manufacturers especially in Malaysia. The live trials have served as an eye-opener and hence created awareness on how this technology can improve the productivity as well as worker safety and health of participating manufacturers.

3. Healthcare

The technology developed has helped health professionals such as physiotherapist, doctors, trainers, athletes and soldiers in providing a better healthcare within the Brunei community and beyond within ASEAN, in particular athletes, soldiers and patients with gait abnormality. When coupled with real-time location, a richer context can be derived for more holistic healthcare.

(5) Future Developments

To improve user experience in all walks of life, it is important to build a smarter indoor environment that is aware of dynamic object (human/machine) presence, their behaviours, status and needs, in order to activate or deliver the right actions. For future developments, an Advanced Ambient Intelligence (AAI) platform is proposed. This platform is expected to bring intelligence to our environments and makes those environments sensitive to us. The key element of AAI is context discovery, which can be realised by determining not only the location but also the surrounding condition of the object of interest. More importantly the environment is not only aware but are react proactively. Ultimately the ultimate vision to have a smarter and safer spaces for all walks of life.

(6) Social Contributions

1) Publications
   i) KS Yeo, A Ting, SC Ng, D Chieng and N Anas, "**Wi-Fi Indoor Positioning Fingerprint Health Analysis for a Large Scale Deployment**," International Journal on Advanced Science, Engineering and Information Technology (IJASEIT 2018), vol. 8, no. 4-2, pp. 1411-1416, 2018.
   ii) Viet-Cuong Ta, Trung-Kien Dao, Dominique Vaufreydaz, Eric Castelli, **"Smartphone-Based User Positioning in a Multiple-User Context with Wi-Fi and Bluetooth"**, 2018 International Conference on Indoor Positioning and Indoor Navigation (IPIN 2018), 24-27 September 2018, Nantes, France.
   iii) Arosha Senanayake S.M.N., Khairiyah Binti Haji Raub S.A.., Naim A.G., Chieng D. (2019) "**Array of Things for Smart Health Solutions Injury Prevention**", Performance Enhancement and Rehabilitation., Vol. 1, pp. 598-615, October 2018, In: Arai K., Bhatia

R., Kapoor S. (eds) Advances in Intelligent Systems and Computing, vol 880. Springer, Cham, DOI: https://doi.org/10.1007/978-3-030-02686-8_45.

iv) S. M. N. Arosha Senanayake, N. H. Kadir, M. S. A. Bin Suhaimi and M. Sasaki, "**Master-Slave IoT for Active Healthy Life Style**", 2019 12th International Conference on Human System Interaction (HSI), Richmond, VA, USA, 2019, pp. 151-157, doi: 10.1109/HSI47298.2019.8942640.

v) Mohd Faiz, David Chieng, Alvin Ting, SC Ng, Idawaty, "**Performance Analysis of Enhanced Delta Sampling Algorithm for BLE Indoor Localization**", 2nd Future Smart Cities (FSC 2019), Xiamen University, Sepang, Malaysia, 5-6 Nov 2019.

vi) Huan-Bang Li, Ryu Miura, Hisashi NISHIKAWA, Toshinori KAGAWA, Fumihide KOJIMA, "**Proposals and Implementation of High Band IR-UWB for Increasing Propagation Distance for Indoor Positioning**", IEICE Transactions on Fundamentals of Electronics Communications and Computer Sciences (IEICE), E101.A(1):185-194, DOI: 10.1587/transfun.E101.A.185.

vii) Alvin Ting, David Chieng, Chrishanton V. Sebastiampi, Putri S. Khalid, "**High Precision Location Tracking Technology in IR4.0**", Journal of Advances in Technology and Engineering Research (JATER2019), TAF Publishing, ISSN: 2414-4592, DOI: 10.20474/jater-5.3.4, 2019.

viii) Viet-Cuong Ta, Trung-Kien Dao, Dominique Vaufreydaz, Eric Castelli, "**Collaborative Smartphone-Based User Positioning in a Multiple-User Context Using Wireless Technologies**", Sensors 20(2): 405 (2020)

ix) Dinh-Van Nguyen, Trung-Kien Dao, Eric Castelli, Fawzi Nashashibi, "**A fusion method for localization of intelligent vehicles in carpark**". Access, IEEE, ISSN: 2169-3536, 2020. (accepted)

x) Arosha Senanayake S.M.N., Naim A.G., "**Smart Sensing and Biofeedback for Vertical Jump in Sports**", Mukhopadhyay S., Jayasundera K., Postolache O. (eds) Modern Sensing Technologies. Smart Sensors, Measurement and Instrumentation, vol 29. pp. 63-81, Springer, Cham.

2) Patent (international or domestic)
   i) Huan-Bang Li et. al., NICT, "Radio Receiver", US 10,277, 263 B2, USPTO (status granted)
   ii) David Chieng, Alvin Ting, MIMOS, "**System and Method for Locating a Device in an Indoor Environment**", PI 2018001828, Filed at MyIPO (30-Oct-18).
   iii) David Chieng, Alvin Ting, MIMOS, "**Method for Self-Repairing Wireless Signal Fingerprint Database**", PI 2018002217, Filed at MyIPO (29-Nov-18).
   iv) David Chieng, Alvin Ting, MIMOS, "System and Method For Estimating Geospatial Position", PI 2018002738, Filed at MyIPO (31-Dec-18)
   v) David Chieng et. al., MIMOS, "**System and Method for Real-Time Object Tracking**", PI20180002075, Filed at MyIPO (15-Nov-19)
   vi) SMN Arosha Senanayake, Nursyuhada Binti Hj Kadir, "**Transient healthcare smartwatch operating system and method**", bn/n/2020/0065, intellectual property office (IPO), Brunei Darussalam.

3) Talks and Exhibitions of the application or system the project developed.
   i) Malaysia Cloud and Datacenters Convention 2018, Bangsar South, Kuala Lumpur
   ii) Hypernet of Things (HOT) 2018, MITI Tower, Kuala Lumpur, Malaysia
   iii) Smart Factory 2019, MIGHT, Cyberjaya, Selangor, Malaysia
   iv) Talk on IoT 2019, Sarawak Energy, Kuching, Sarawak
   v) INDUSTRY4WRD SUMMIT 2019, MITI Tower, Kuala Lumpur, Malaysia.

Figure 14: Talk at Sarawak Energy on IoT

Figure 15: Public Exhibition at INDUSTRY4WRD SUMMIT 2019